AMENDMENTS TO THE SPECIFICATION

Please replace the paragraph at page 1, lines 10-15 with the following rewritten paragraph:

The present invention relates to estimating **the** precise position of a stationary or moving object using multiple satellite signals and a network of multiple receivers. The present invention is particularly suited to position estimation in real-time kinetic environments where it is desirable to take into account the spatial distribution of the ionosphere delay.

Please replace the paragraph at page 1, lines 17-28 with the following rewritten paragraph:

Satellite navigation systems, such as GPS (USA) and GLONASS (Russia), are intended for ~~accuracy~~ **accurate** self-positioning of different users possessing special navigation receivers. A navigation receiver receives and processes radio signals broadcast by satellites located within line-of-sight distance, and from this, computes the position of the receiver within a ~~pre-defined~~ **predefined** coordinate system. However, for military reasons, the most accurate parts of these satellite signals are encrypted with codes only known to military users. Civilian users cannot access the most accurate parts of the satellite signals, which makes it difficult for civilian users to achieve accurate results. In addition, there are sources of noise and error that degrade the accuracy of the satellite signals, and consequently reduce the accuracy of computed values of position. Such sources include carrier ambiguities, receiver time offsets, and atmospheric effects on the satellite signals.

Please replace the paragraph at page 2, lines 10-27 with the following rewritten paragraph:

In a first aspect of the present invention, an exemplary apparatus/method comprises receiving the known locations of a first base station and a second base station, obtaining a time offset representative of the time difference between the clocks of the first and second base stations, and obtaining measured satellite data as received by the rover, the first base station, and the second base station. The measured satellite data comprises pseudo-range information. The exemplary apparatus/method generates a first set of residuals of differential navigation equations associated with a set of measured pseudo-ranges related to a first baseline (R–B1) between the rover and the first base station. The residuals are related to the measured satellite data received

by the rover station and the first base station, the locations of the satellites, and the locations of the rover station and the first base station. The exemplary apparatus/method also generates a second set of residuals of differential navigation equations associated with a set of measure pseudo-ranges related to a second baseline (R–B2) between the rover and the second base station. These residuals are related to the measured satellite data received by the rover station and the second base station, the locations of the satellites, and the locations of the rover station and the second base station. The exemplary apparatus/method estimates the rover's location from the first set of residuals, the second set of residuals, **and** the time offset between the clocks of the first and second base stations.

Please replace the paragraph at page 3, lines 7-17 with the following rewritten paragraph:

In a fourth aspect of the present invention, which may be applied with any of the aspects of the present invention described herein, the exemplary apparatus/method obtains measured satellite carrier phase data as received by the rover and the first base station (the first ~~**base line**~~ **baseline**). The exemplary apparatus/method generates a fourth set of residuals of differential navigation equations associated with a set of measured carrier phase data related to the first ~~**base line**~~ **baseline**, and resolves the cycle ambiguities in the carrier phase data from the fourth residual and one or more of the first, second, and third residuals. The resolved cycle ambiguities may take the form of floating ambiguities, fixed-integer ambiguities, and/or integer ambiguities. The exemplary apparatus/method estimates the rover's location further with the fourth set of residuals and the resolved cycle ambiguities associated with the first ~~**base line**~~ **baseline**.

Please replace the paragraph at page 3, lines 18-32 with the following rewritten paragraph:

In a fifth aspect of the present invention, which may be applied with any of the aspects of the present invention described herein, the exemplary apparatus/method obtains measured satellite carrier phase data as received by the second base station, and further obtains a set of cycle ambiguities related to a set of satellite phase measurements associated with the baseline between the first and second base stations (B1-B2). The exemplary apparatus/method generates a fifth set of residuals of differential navigation equations associated with a set of measured carrier phase data related to the second base line between the rover and the second base station

(R-B2), and resolves the cycle ambiguities in the carrier phase data from the fifth residual, the set of cycle ambiguities associated with the baseline between the first and second base stations, and one or more of the first, second, third, and fourth residuals. The resolved cycle ambiguities may take the form of floating ambiguities, fixed-integer ambiguities, and/or integer ambiguities. The exemplary apparatus/method estimates the rover's location further with the fifth set of residuals and the resolved cycle ambiguities associated with the second ~~**base line**~~ **baseline** (R-B2).

Please replace the paragraph at page 4, lines 15-27 with the following rewritten paragraph:

In a seventh aspect of the present invention, which may be applied with any of the aspects of the present invention described herein, the exemplary apparatus/method obtains a first set of first ionosphere delay differentials associated with the satellite signals received along the ~~**base line**~~ **baseline** formed by the first and second base stations, and generates ionosphere delay corrections to one or more of the above-described first through sixth residuals from the first set of first ionosphere delay differentials, the locations of the first and second base stations, and an estimated location of the rover station. As a further option, the exemplary apparatus/method obtains **a** set of second ionosphere delay differentials associated with the satellite signals received along the ~~**base line**~~ **baseline** formed by the first and third base stations (or the ~~**base line**~~ **baseline** formed by the second and third base stations), and generates the ionosphere delay corrections to the one or more of the above-described first through sixth residuals further from the second set of ionosphere delay differentials and the location of the third base station.

Please replace the paragraph at page 4, line 28-32 with the following rewritten paragraph:

In an **[[eight]]** **eighth** aspect of the present invention, which may be applied to the seventh and further aspects of the present invention described herein, the exemplary apparatus/method forms one or more of the first through sixth residuals to account for second order effects in the ionosphere delay corrections applied to the baselines associated with the rover, and further generates an estimate of the second order effects.

Please replace the paragraph at page 5, lines 17-24 with the following rewritten paragraph:

In an eleventh aspect of the present invention, which may be applied with any aspects of the present invention described herein which account for ionosphere delays, the exemplary apparatus/method generates the first set of first ionosphere delay differentials, and optionally the second set of first ionosphere delay differentials. As a further option, the apparatus/method generates a third set of ionosphere delay differentials associated with the satellite signals received along the **~~base line~~** **baseline** formed by the second and third base stations, and generates therefrom three sets of ionosphere delay differentials which are **~~self consistent~~** **self-consistent**.

Please replace the paragraph starting at page 6, line 19 and ending at page 7, line 4 with the following rewritten paragraph:

FIG. 1 is a perspective view of a rover station (R) and three base stations (B1, B2, B3) in an exemplary network according exemplary embodiments of the present invention, and FIG. 2 is a top-plan schematic drawing thereof. The present invention pertains to estimating the position of the rover station with information provided from two or three of the base stations and with satellite measurements made by the rover station. Referring to FIG. 1, each station has a receiver that receives the satellite positioning signals with a satellite antenna (shown as a substantially flat disk). A plurality of satellites S1-S4 are depicted in FIG.1, with the range between each satellite and each antenna being depicted by a respective dashed line. In the example shown **[[and]]** **in** FIG. 1, the Rover station is operated by a human user, and has a positioning pole for positioning the Rover's satellite antenna over a location whose coordinates are to be determined. The Rover's satellite antenna is coupled to the receiver's processor, which may be disposed in **[[the]]** **a** backpack and carried by the user. The user interacts with the receiver's processor through a keypad/display. The receiver also has a radio modem (more formally a demodulator) that can receive data from the base stations through a conventional RF antenna and relay it to the processor. In other embodiments, the Rover's satellite antenna may be mounted to a vehicle, and the receiver may operate independently and automatically without the need of a human operator. The present invention is applicable to these and other physical embodiments.

Please replace the paragraph at page 7, lines 5-16 with the following rewritten paragraph:

The satellite signals comprise carrier signals which are modulated by pseudo-random binary codes, which are then used to measure the delay relative to **a** local reference clock or oscillator. These measurements enable one to determine the so-called pseudo-ranges between the receiver and the satellites. The pseudo-ranges are different from true ranges (distances) between the receiver and the satellites due to variations in the time scales of the satellites and receiver and various noise sources. To produce these time scales, each satellite has its own on-board atomic clock, and the receiver has its own on-board clock, which usually comprises a quartz crystal. If the number of satellites is large enough (four or more), then the measured pseudo-ranges can be processed to determine the user location (*e.g.*, X, Y, and Z coordinates) and to reconcile the variations in the time scales. Finding the user location by this process is often referred to as solving a navigational problem or task.

Please replace the paragraph at page 7, lines 17-27 with the following rewritten paragraph:

More specifically, the GPS system employs a constellation of satellites in orbit around the earth at an altitude of approximately 26,000 km. Each GPS satellite transmits microwave radio signals in two frequency bands located around 1575.42 MHz and 1227.6 MHz, referred to as L1 band and L2 band, respectively. The GPS L1-band signal is modulated by a coarse/acquisition code (C/A) and a precision ranging code (P-code). The L2-band signal is binary modulated by the P-code. The GPS C/A code is a pseudo-random (PR) Gold code that is specific to each satellite and is used to identify the source of a received signal. The P-code is a pseudo-random code ~~**signals**~~ **signal** and is also specific to each satellite, having a symbol rate which is ten time more than C/A, which reduces the granularity by a factor of ten. The GPS satellite transmission standards are set in detail by the *ICD-GPS-200, Revision C, ARINC Research Corporation, 10 October, 1993.*

Please replace the paragraph at page 8, lines 5-23 with the following rewritten paragraph:

The distance between a receiver and a satellite (called the "receiver-to-satellite range") is determined by measuring the time that it takes for the signal to pass from the satellite to the receiver, provided that the position of the satellite is known. The satellites and receivers have internal clocks

that are synchronized to a single GPS time. For each satellite signal being tracked, the receiver generates a local version of the satellite's expected PR-code, and then retards that version in time until the local version correlates (*i.e.*, matches) with the received satellite signal. Thereafter, the satellite signal is tracked by advancing or retarding the local version of the PR-code. The carrier phase of the satellite can also be tracked, which is usually done by tracking the Doppler shift of the satellite signal. The positions of the satellites are, except for minor variations, highly predictable as a function of time, and the receiver generally carriers a model of the satellite's position as a function of GPS time. In theory, by determining the ranges to three different satellites, the receiver can perform a three-dimensional triangulation to find its position. But because **of** limitations in the accuracy of the receiver's clock, the internally generated time is offset somewhat from true GPS time. Thus, the ranges to at least four different satellites are simultaneously measured in order to be able to solve for four unknowns, namely the three coordinates of the position of the receiver location (*e.g.*, x, y, and z) and an offset of the receiver clock time from the GPS time. The location is usually performed with respect **to** the defined Cartesian coordinates frame.

Please replace the paragraph starting at page 8, line 30 and ending at page 9, line 9 with the following rewritten paragraph:

The desire to guarantee the solution of navigational tasks with accuracy better than 10 meters, and the desire to raise the stability and reliability of measurements, have led to the development of the mode of "differential navigation ranging," also called "differential navigation" (DN). In the DN mode, the task of finding the user position is performed relative to a Base station (Base), the coordinates of which are known with **[[the]]** high accuracy and precision. The Base station has a navigation receiver that receives the signals of the satellites and processes them to generate measurements. The results of these measurements enable one to calculate corrections, which are then transmitted to a roving GPS receiver, which the user has set up. We call this GPS receiver the "Rover station," or "Rover receiver." By using these corrections, the roving GPS receiver gains the ability to compensate for the major part of the strongly correlated errors in the measured pseudo-ranges, and to substantially improve the accuracy of the estimate of its position.

Please replace the paragraph at page 12, lines 13-21 with the following rewritten paragraph:

Even with all of ~~the above described~~ **the above-described** processing to account for clock offsets and carrier ambiguities, there are additional factors which affect the accuracy of measurements made with GPS and/or GLONASS signals. As one factor, the trajectory of each satellite (or its initial data called the ephemeris), is elliptical and is affected by natural causes such as solar winds. The accuracy of any measurement is dependent upon knowledge of the position of the satellites at **a** certain time. An estimate of the ephemeris is calculated on earth for each of the satellites and is periodically uploaded to the satellite. The position information of a satellite is encoded onto a low frequency (50 Hz) signal which is modulated on to one of the carrier signals, and transmitted to the GPS receiver on earth.

Please replace the paragraph at page 12, lines 22-33 with the following rewritten paragraph:

Two additional and important factors that affect the accuracy of measurements made with GPS and/or GLONASS signals are the effects of the troposphere and ionosphere on propagation of signals from the satellites to the receivers. The troposphere is the lower part of the atmosphere and variations in the temperature, pressure, and humidity lead to spatial variations in the signal propagation. The ionosphere is at the upper part of the atmosphere and has a slice of ionized gas at the altitude of around 300 km. The density of ionized particles is sufficiently high to affect the propagation of electromagnetic signals, and has a spatial variation and a time variation. The ionosphere effect becomes even more important during years of high solar activity. These variations in the troposphere and ionosphere introduce variable delays in the propagation **of** the satellite signals to the receivers. If the base and rover are widely separated, these delays will be significantly different for the base and rover stations, and will introduce error into the estimation of the rover's position.

Please replace the paragraph at page 13, lines 1-12 with the following rewritten paragraph:

With that general overview, we now describe the invention in greater detail. For the sake of simplifying the presentation, and without loss of generality, we assume "N" satellites identified by the index "s", $s = 1, \ldots, N$, and we assume that each receiver can track the satellite's

L1 band signal and the ~~**satellites**~~ **satellite's** L2 band signal. The receivers extract timing information from the satellite signals, and report this information **[[a]]** **as** predefined increments k of time, which we call epochs k. The time between epochs can be selected by the user, and generally ranges between 0.1 seconds to 2 seconds, with 1 second being typical. The clocks of all of the receivers are typically accurate to within several milliseconds of the true GPS time, and for practical purposes the receivers can ~~**determined**~~ **determine** the number k of the current epoch from their clocks. The following timing information can be extracted from each satellite "s" at each epoch "k" by each receiver "r":

Please replace the paragraph starting at page 16, line 10 and ending at page 17, line 2 with the following rewritten paragraph:

The difference form of [3A] is generated by forming two ~~**instance**~~ **instances** of form [1A] for receivers "r" and "q", and then subtracting the two instances (the instance for receiver "q" is ~~**subtract**~~ **subtracted** from the instance for receiver "r"). Difference forms [3B], [3C], and [3D], are formed in a similar manner from corresponding instances of forms [1B], [1C], and [1D], respectively. Forms [3A]-[3D] are the single-differences of the navigation equations. The benefit of forming the between-station single differences is that the error term representing the time offset of the satellite clock, τ_k^s, is cancelled out in the differences. We emphasize that the forms [3A]-[3D] can be applied to each satellite that can be observed by receivers "q" and "r." Higher-order differences of the navigation equations, such as the double-differences of the navigation equations, can be formed and are known to the art. For example, a common double-difference equation is the difference between two ~~**singles-difference**~~ **single-difference** equations associated with a common baseline, but with each single-difference equation being based on a different satellite. The present invention may also use these higher-order differences of the navigation equations, although the single differences of the navigation equations are currently preferred. Each of these difference forms is generically referred to as a differential navigation equation.

Please replace the paragraph at page 17, lines 5-26 with the following rewritten paragraph:

Because the locations of the base stations are known, and because the locations of the satellites as a function of epoch time (k) are also known, the ~~**between station**~~ **between-station** differences of each true range $\Delta_{q,r}R_k^s = R_{r,k}^s - R_{q,k}^s$ associated with each satellite "s" can be generated from existing information. If vectors $\mathbf{X_r}$, $\mathbf{X_q}$, and $\mathbf{X^s}$ represent the locations of receiver "r", receiver "q", and satellite "s", respectively, in a coordinate system (*e.g.*, **a** Cartesian coordinate system), and the operator $\|\cdot\|$ ~~**represent**~~ **represents** the distance operator in that coordinate system, then $\Delta_{q,r}R_k^s = \| \mathbf{X^s} - \mathbf{X_r} \| - \| \mathbf{X^s} - \mathbf{X_q} \|$. This reduces by one the number of unknowns in forms [3A]-[3D]. In addition, the Goad-Goodman model may be used to model the difference in ~~**troposphere**~~ **tropospheric** effects (with an error less than a few percent), and thus the difference $\Delta_{q,r}T_k^s$ may be estimated based on the positions of the receivers and the satellite (more specifically, the angles between the receivers and ~~**satellites**~~ **satellite**). The noise sources $\Delta_{q,r}n^{L1,s}$, $\Delta_{q,r}n^{L2,s}$, $\Delta_{q,r}v^{L1,s}$, and $\Delta_{q,r}v^{L2,s}$ can never be known, but they are generally zero-mean and their effect can be reduced by averaging. Thus, the number of solvable unknowns in forms [3A]-[3D] may be reduced to the following six: (1) $\Delta_{q,r}\tau_k$, (2) $\Delta_{q,r}I_k^s$, (3) $\Delta_{q,r}N^{L1,s}$, (4) $\Delta_{q,r}\psi^{L1}$, (5) $\Delta_{q,r}N^{L2,s}$ **, and** (6) $\Delta_{q,r}\psi^{L2}$. The first unknown varies with time and is common to all of the satellites being tracked by receivers "q" and "r." The second unknown varies with time and is specific to the satellite "s" being tracked by the pair of receivers "q" and "r." The third and fifth unknowns are each specific to the satellite "s" being tracked by the pair of receivers "q" and "r", and each does not normally vary with time unless a cycle slip occurs in the ~~**receivers**~~ **receiver's** phase-lock loop. The **[[forth]]** **fourth** and sixth unknowns are specific to the pair of receivers "q" and "r," and do not normally vary with time.

Please replace the paragraph starting at page 18, line 27 and ending at page 19, line 4 with the following rewritten paragraph:

Forms [4A]-[4D] comprise the known terms of the single-differences of the navigation equations, and we call them the "residuals" of the single differences, or more generally the

"residuals of a set of differential navigation equations." The magnitude of each residual is generally less than the magnitudes of one or more of the known terms that **[[forms]]** **<u>form</u>** the residual.

Please replace the paragraph at page 19, lines 5-10 with the following rewritten paragraph:

Then, the unknowns can be estimated from the residuals using the following forms by any of **<u>a</u>** number of solution methods known to the art:

$$\Delta_{q,r} b_k^{L1,s} = -c\Delta_{q,r}\tau_k + \Delta_{q,r} I_k^s + \Delta_{q,r} n_k^{L1,s} \qquad [5A]$$

$$\Delta_{q,r} b_k^{L2,s} = -c\Delta_{q,r}\tau_k + \left(\frac{\lambda^{L2,s}}{\lambda^{L1,s}}\right)^2 \Delta_{q,r} I_k^s + \Delta_{q,r} n_k^{L2,s} \qquad [5B]$$

$$\Delta_{q,r} p_k^{L1,s} = -f^{L1,s}\Delta_{q,r}\tau_k - \frac{1}{\lambda^{L1,s}}\Delta_{q,r} I_k^s + \Delta_{q,r}\hat{N}^{L1,s} + \Delta_{q,r} v_k^{L1,s} \qquad [5C]$$

$$\Delta_{q,r} p_k^{L2,s} = -f^{L2,s}\Delta_{q,r}\tau_k - \frac{\lambda^{L2,s}}{\left(\lambda^{L1,s}\right)^2}\Delta_{q,r} I_k^s + \Delta_{q,r}\hat{N}^{L2,s} + \Delta_{q,r} v_k^{L2,s} \qquad [5D]$$

Please replace the paragraph at page 22, lines 5-8 with the following rewritten paragraph:

The solvable unknowns for form [9] ~~**includes**~~ **<u>include</u>** δX_k, as well as $\Delta_{q,0}\tau_k$, $\Delta_{q,0} I_k^s$, $\Delta_{q,0}\hat{N}^{L1,s}$, and $\Delta_{q,0}\hat{N}^{L2,s}$. As described below in greater detail, estimation processes for these unknowns generally include instances of forms [9A]-[9D] for several satellites, and for several epochs of time.

Please replace the paragraph at page 24, lines 7-20 with the following rewritten paragraph:

According to general aspects of the present invention, the position of the Rover is estimated by forming a primary baseline between the Rover and one of the base stations, usually the closest base station, and then forming one or more secondary baselines from the Rover to other base stations. Then, one or more of the above relationships are applied to the configuration of stations to relate the measured data associated with the secondary baseline(s) with the

measured data associated **with the** primary ~~baseline~~ **baseline,** using one or more of the unknowns associated with the baselines between base stations through forms [11]. To simplify the presentation of the present invention, and without loss of generality, we will use base station B1 to form the primary baseline with the Rover, and we use base stations B2 and B3 to form the secondary baselines with the Rover. Varying amounts **of** measured data from the secondary baselines may be related with the primary baseline. In general, the greater amount of information so related increases the accuracy of the estimated position of the rover, and/or enables a greater spacing between base stations.

Please replace the paragraph at page 25, lines 10-19 with the following rewritten paragraph:

The terms in forms [12A], [14A], and [16A] are the residuals of differential navigation equations and are known. The unknowns are contained in **the** right-hand sides of forms [13A], [15A], and [17A]. There are a total of six solvable unknowns: $\Delta_{1,0}\tau_k$, $\Delta_{2,0}\tau_k$, $\Delta_{3,0}\tau_k$, and the three components of δX_k. However, using form [11A], $\Delta_{2,0}\tau_k$ may be related to $\Delta_{0,1}\tau_k$ through the estimated base-station time offset $\Delta_{2,1}\tau_k$ as follows: $\Delta_{2,0}\tau_k = \Delta_{2,1}\tau_k - \Delta_{0,1}\tau_k = \Delta_{2,1}\tau_k + \Delta_{1,0}\tau_k$. In a similar manner, $\Delta_{3,0}\tau_k$ may be related to $\Delta_{0,1}\tau_k$ through the estimated base-station time offset $\Delta_{3,1}\tau_k$ as follows: $\Delta_{3,0}\tau_k = \Delta_{3,1}\tau_k - \Delta_{0,1}\tau_k = \Delta_{3,1}\tau_k + \Delta_{1,0}\tau_k$. These two forms reduce **the** number of true solvable unknowns to four, and the following modified set of forms may be used to estimate the true solvable unknowns:

Please replace the paragraph at page 25, lines 25-27 with the following rewritten paragraph:

As an equivalent, one may view forms $\Delta_{2,0}\tau_k = \Delta_{2,1}\tau_k + \Delta_{1,0}\tau_k$ and $\Delta_{3,0}\tau_k = \Delta_{3,1}\tau_k + \Delta_{1,0}\tau_k$ as increasing the total number of forms by two, and may then estimate the six unknowns **of** the expanded form set:

Please replace the paragraph at page 26, lines 4-8 with the following rewritten paragraph:

The rover's location ($X_0 = \overline{X}_0 + \delta X_k$) may be estimated from each of the above form sets using any one of several [[**know**]] **<u>known</u>** methods. Here, we demonstrate estimating the rover's location with a least squares fitting approach based on the first form set. After generating the residuals $\Delta_{1,0}b_k^{L1,s}$ for N satellites (s=1 to s=N) for the baseline between the rover and the first base station (R–B1), we collect them together into a first vector:

Please replace the paragraph starting at page 27, line 13 and ending at page 28, line 2 with the following rewritten paragraph:

For the reader not familiar with the GPS art, we briefly note that matrix $\mathbf{C}_{n,k}$ generally comprises a diagonal matrix, with each diagonal element being related to the noise sources in the two receivers that define the baseline (in this case the rover and one of the base stations). A covariance factor is usually associated with each satellite signal received by each receiver, and this covariance factor is usually related to the signal-to-noise ratio of the signal (as received by the receiver) and the elevation angle of the satellite (the multipath error has a strong correlation with the elevation angle). Each diagonal entry of matrix $\mathbf{C}_{n,k}$ usually comprises an addition of the two covariance factors associated with the two receivers which **~~contributed~~** **<u>contribute</u>** to the underlying noise quantity, *e.g.*, base station B1 and the rover for noise quantity $\Delta_{1,0}n_k^{L1,s}$. For more details and information on the generation of the covariance matrices, the reader is **~~direct~~** **<u>directed</u>** to A. Leick, <u>GPS Satellite Surveying</u>, John Wiley & Sons, (1995). Matrix $\mathbf{A}_k^*$ is known as the observation matrix, and it relates the solvable unknowns to the residuals. The solvable unknowns may also be estimated by other processes, such as various Kalman filtering processes.

Please replace the paragraph starting at page 28, line 15 and ending at page 29, line 5 with the following rewritten paragraph:

Thus, the above exemplary embodiments provide methods of estimating the location of the rover station (R) with the use of a first base station (B1) a second base station (B2), and optionally a third base station (B3) or more base stations. In summary, the locations of the base stations were obtained, and one of the base stations (e.g., B1) was selected to form a primary baseline with the Rover station. We refer to this base station as the primary base station, and the other base stations as the secondary base stations. Additionally, for each of the secondary base stations, the time offset representative of the time difference between the clocks of the primary station and secondary base station is obtained. Also, measured satellite data as received by the rover, the primary base station, and the secondary base station(s) is obtained. From this, the set of residuals $\Delta_{1,0}\mathbf{B}_k^{L1}$ associated with the primary baseline (R–B1) is generated, and is related to the measured satellite data received by the rover station and the first base station, the locations of the satellites, and the locations of the rover station and the first base station. Similarly, the set(s) of residuals $\Delta_{2,0}\mathbf{B}_k^{L1}$, $\Delta_{3,0}\mathbf{B}_k^{L1}$, *etc.* associated with the secondary baseline(s) are generated, each set of residuals **<u>being</u>** related to the measured satellite data received by the rover station and the secondary base station, the locations of the satellites, and the locations of the rover station and the secondary base station. Thereafter, the rover's location is estimated from the above sets of residuals, the time offset between the clocks of the base stations, and typically an observation matrix.

Please replace the paragraph at page 31, line 14 and ending at page 32, line 2 with the following rewritten paragraph:

The terms in forms [12C, D], [14C, D], and [16C, D] are the residuals of the differential navigation equations and are known. The unknowns are contained on the right-hand sides of forms [13C, D], [15C, D], and [17C, D]. For *N* satellites, there are 6**N* equations and a total of (6+ 6**N*) solvable unknowns: $\Delta_{1,0}\tau_k$, $\Delta_{2,0}\tau_k$, $\Delta_{3,0}\tau_k$, the three components of δX_k, and *N* instances of each of $\Delta_{1,0}\hat{N}^{L1,s}$, $\Delta_{2,0}\hat{N}^{L1,s}$, $\Delta_{3,0}\hat{N}^{L1,s}$, $\Delta_{1,0}\hat{N}^{L2,s}$, $\Delta_{2,0}\hat{N}^{L2,s}$, and

$\Delta_{3,0}\hat{N}^{L2,s}$ for $s = 1$ to $s = N$ satellites. However, using forms [11A], [11C], and [11D], the number of unknowns may be reduced to 4+2*N. As we saw above, $\Delta_{2,0}\tau_k$ may be related to $\Delta_{0,1}\tau_k$ through the estimated base-station time offset $\Delta_{2,1}\tau_k$ using form [11A] as follows: $\Delta_{2,0}\tau_k = \Delta_{2,1}\tau_k - \Delta_{0,1}\tau_k = \Delta_{2,1}\tau_k + \Delta_{1,0}\tau_k$. In a similar manner, $\Delta_{3,0}\tau_k$ **[[was]]** **may be** related to $\Delta_{0,1}\tau_k$ through the estimated base-station time offset $\Delta_{3,1}\tau_k$ as follows: $\Delta_{3,0}\tau_k = \Delta_{3,1}\tau_k - \Delta_{0,1}\tau_k = \Delta_{3,1}\tau_k + \Delta_{1,0}\tau_k$. Form [11C] may be used to ~~related~~ **relate** each of the L1 band ambiguities of the secondary baselines to the primary baseline as follows:

Please replace the paragraph at page 34, lines 11-15 with the following rewritten paragraph:

The solvable unknowns $\left[\delta X_k, \Delta_{1,0}\tau_k, \Delta_{1,0}\hat{\mathbf{N}}^{L1}, \Delta_{1,0}\hat{\mathbf{N}}^{L2}\right]^T$ may be estimated by applying a number of processes to the combination of forms [21] and [18+]. Further below, in a subsequent section, we ~~described~~ **describe** a preferred process that can be used on the combination of forms [21] and [18+]. Here, we describe how a least squares process may be applied to combined forms of [18+] and [21].

Please replace the paragraph at page 35, lines 2-4 with the following rewritten paragraph:

A least squares process is applied to form [23] to generate the floating ambiguities over several epochs, and the floating ambiguities are averaged to generate **[[a]]** **an** estimate of the floating ambiguities. For each epoch, the following may be generated:

Please replace the paragraph at page 37 lines 7-11 with the following rewritten paragraph:

where $\mathbf{A}^*_{24,k}$ is the observation matrix of form [24] (the matrix which is multiplying the solvable unknowns in form [24]). In form [25], the floating ambiguities may be used in place of the fixed-integer ambiguities. However, lower accuracy generally results, although the estimation speed is increased since the step of generating the ~~fix-integer~~ **fixed-integer** ambiguities from the floating ambiguities may be omitted.

Please replace the paragraph starting at page 37, line 12 and ending at page 38, line 8 with the following rewritten paragraph:

With **the** large amount of measurement data afforded by the present invention, various residuals may be omitted from use in the estimation process. For example, we may **[[only]]** work **only** with L1-band data of all three stations and [[only]] use **only** the residuals associated with this data. We may also **[[only]]** work **only** with data and residuals from two base stations (the primary baseline and one secondary baseline). For applications needing lower accuracy, we may work with the phase and ~~pseudorange~~ **pseudo-range** data of the primary baseline (R-B1) and just the ~~pseudorange~~ **pseudo-range** data or phase data of one of the secondary baselines. Also, one can undertake an analysis of the satellite constellation and select the satellites which should provide the highest accuracy, using the pseudo-range and phase data from the L1- and L2- bands. Finally, while we have illustrated the invention with the single-difference navigation equations, it may be appreciated that higher-order differences of the navigation equations may be used. Such higher-order differences have known quantities (which form the residuals) and similar unknowns to be solved for, which can be solved by the above-described methods.

Please replace the paragraph at page 39, lines 2-20 with the following rewritten paragraph:

In the above embodiments, the ionosphere delays were assumed to equally affect the rover and base stations, and the between-station differences were neglected. When the base stations and rover are separated by large distances, better accuracy may be obtained by taking into account the ionosphere delays. This can be done in a number of ways according to the present invention. FIG. 3 provides a representation of the ionosphere delays of one satellite "s" at the base and rover stations. Shown is a 3-d Cartesian system having two planar axes, north (n) and east (e), to represent the terrain on which the stations are located, and a vertical axis to represent the ionosphere delays of a satellite "s" as a function of the terrain. The ionosphere delay will be different for each satellite. The locations of the rover station R and three base stations B1, B2, and B3 are indicated in the north-east plane of the figure. The ionosphere delays for each of these stations are indicated as $I^s_{0,k}$, $I^s_{1,k}$, $I^s_{2,k}$ and $I^s_{3,k}$, respectively. The preferred embodiments of the processing of the base station data, which is more fully described below,

generates estimates for the ~~between base stations~~ **between-base station** differences in the ionosphere delays $\Delta_{1,2}I_k^s$, $\Delta_{1,3}I_k^s$, and $\Delta_{2,3}I_k^s$, which we call ionosphere delay differentials. From two of these differentials, an estimate for the ionosphere delay between the rover and any of the base stations can be generated. Here, we are most interested in the difference $\Delta_{1,0}I_k^s$ associated with the primary baseline, the one between the rover and the first base station.

Please replace the paragraph starting at page 43, line 18 and ending at page 44, line 22 with the following rewritten paragraph:

Having thus described three general groups of embodiments, we now describe an exemplary rover station 100 in FIG. 5 that may be used to implement any of the above-described embodiments. ~~Description~~ **A description** of rover station 100 is provided in conjunction with a flow diagram shown in FIG. 6. Referring to FIG. 5, rover 100 comprises a GPS antenna 101 for receiving navigation satellite signals, **[[and]]** **an** RF antenna 102 for receiving information from the base stations, a main processor 110, an instruction memory 112 **[[and]]** **a** data memory 114 for processor 110, and a keyboard/display 115 for interfacing with a human user. Memories 112 and 114 may be separate, or ~~difference~~ **different** sections of the same memory bank. Rover 100 further comprises a satellite-signal demodulator 120 for generating the navigation data $\rho_{0,k}^{L1,s}$, $\rho_{0,k}^{L2,s}$, $\phi_{0,k}^{L1,s}$, and $\phi_{0,k}^{L2,s}$ for each epoch *k* from the signals received by GPS antenna 101, which is provided to processor 110. Rover 100 also comprises a base-station information demodulator 130 that receives information signals from the base stations by way of RF antenna 102. Demodulators 120 and 130 may be of any conventional design. The information received by demodulator 130 includes the positions (X_1, X_2, X_3) of the base stations, the satellite-navigational data (e.g., *k*, $\rho_{r,k}^{L1,s}$, $\rho_{r,k}^{L2,s}$, $\phi_{r,k}^{L1,s}$, and $\phi_{r,k}^{L2,s}$, r =1,2,3) received by each base station at each epoch *k*, and the between-base station unknowns (e.g., $\Delta_{r,q}\tau_k$, $\Delta_{r,q}N^{L1,s}$, $\Delta_{r,q}\psi^{L1}$, *etc.*, {r,q} = {1,2},{2,3},{3,1}). Each set of information may be transmitted on a respective frequency channel. The between-base station unknowns may be generated by the first base

station B1, and thereafter transmitted to the rover by the first base station. The first base station may receive the satellite-navigation data from the other base stations in order to compute the between-base station unknowns. Methods of generating the between-base station unknowns are described below in greater detail in the section entitled Between Base Station Processing, Part II. As another approach, the **~~between the~~** **between-base** station unknowns may be generated by rover 100 locally by a between-base station processor 140, which receives the positions of the base stations and their satellite navigation data from base station information to modulator 130. Processor 140 may implement the same methods described in greater detail in the below section entitled Between Base Station Processing, Part II. In addition, processor 140 may comprise its own instruction and data memory, or may be implemented as part of main processor 110, such as by being implemented as a sub-process executed by main processor 110.

Please replace the paragraph starting at page 44, line 23 and ending at page 45, line 5 with the following rewritten paragraph:

Main processor 110 may be configured to implement any **~~and above described~~** **of the above-described** embodiments by the instructions stored in instruction memory 112. We describe implementation of these embodiments with respect to FIG. 6, where certain of the steps may be omitted when not needed by a particular embodiment. In step 202, the locations X_1, X_2, X_3 of the base stations B1, B2, B3 are received by base-station information modulator 130 and conveyed to main processor 110. These locations, and the location of the rover station, are measured at the phase centers of the GPS antennas. Thus, RF antenna 102 and demodulator 130 **~~provides~~** **provide** means for receiving the locations of the first base station and the second base station. Also in step 202, main processor 110 generates an initial estimated location for rover 100, which is relatively **~~course~~** **coarse**. This may be the center of the triangle formed by the base stations, or may be derived from a conventional **~~single point~~** **single-point** GPS measurements (as opposed to a differential GPS measurement), or **[[maybe]]** **may be** generated by other means. The means for performing this step is provided by main processor 110 under the direction of an instruction set stored in memory 112.

Please replace the paragraph at page 45, lines 14-27 with the following rewritten paragraph:

In step 206, main processor 110 is provided with the measured satellite-navigation data (e.g., $\rho_{r,k}^{L1,s}$, $\rho_{r,k}^{L2,s}$, $\phi_{r,k}^{L1,s}$, and $\phi_{r,k}^{L2,s}$) as received by the rover (r=0), the primary base station(r=1), and the secondary base station(s) (r=2,3) at one or more time moments k (epochs). The data is provided by the modulators 120 (for the Rover data) and 130 (for the base station data). Although these sets of data for each epoch k may be received at slightly different times (because the base stations are at different distances from the Rover), the data sets are time-stamped with the epoch identifier (which is conventional practice), and can be stored in a synchronized queue until all the data sets for the epoch are received. Also during this step, main processor 110 determines the positions of the satellites for these time moments from orbital predictions, and ~~**generate**~~ **generates** the computed ranges of the satellites to the rover and base stations based on the positions of the satellites and the stations. The means for performing this step is provided by main processor 110 under the direction of an instruction set stored in memory 112, with the computed information being stored in data memory 114.

Please replace the paragraph at page 46, lines 5-18 with the following rewritten paragraph:

The next step 210 is optional, depending upon the embodiment being implemented. In this step, rover 100 obtains, for each secondary base station, a set of satellite-phase cycle ambiguities related to the baseline between the secondary and primary base stations for one or more of the frequency bands (e.g., L1 and L2) at the time moments k. These ambiguities may be in floating form (e.g, $\Delta_{2,1}\overline{N}^{L1,s}$, $\Delta_{2,1}\overline{N}^{L2,s}$, $\Delta_{3,1}\overline{N}^{L1,s}$, $\Delta_{3,1}\overline{N}^{L2,s}$), fixed-integer form (e.g, $\Delta_{2,1}\hat{N}^{L1,s}$, $\Delta_{2,1}\hat{N}^{L2,s}$, $\Delta_{3,1}\hat{N}^{L1,s}$, $\Delta_{3,1}\hat{N}^{L2,s}$) or integer plus fractional phase form (e.g., $\Delta_{2,1}N^{L1,s}$, $\Delta_{2,1}\psi^{L1}$; $\Delta_{2,1}N^{L2,s}$, $\Delta_{2,1}\psi^{L2}$; $\Delta_{3,1}N^{L1,s}$, $\Delta_{3,1}\psi^{L1}$; $\Delta_{3,1}N^{L2,s}$, $\Delta_{3,1}\psi^{L2}$). Rover 100 may obtain this information by directly receiving it from the primary base station B1 by way of demodulator 130, or may obtain **[[at]]** this information by using between-base station processor 140 to generate it, as indicated above. Either of these approaches provides the means for obtaining this information. As used herein, the term "obtain" encompasses both the receiving

of the information from an outside source (e.g., the primary base station) and the generating the information locally with processor 140.

Please replace the paragraph at page 47, lines 4-7 with the following rewritten paragraph:

As an optional step 216, main processor 110 generates ionosphere corrections and adds **these** corrections to the residuals. The means for performing this step is provided by main processor 110 under the direction of an instruction set stored in memory 112, with the corrections being stored in data memory 114.

Please replace the paragraph at page 47, lines 8-15 with the following rewritten paragraph:

Finally, in step 218, main processor 110 estimates ~~**estimate**~~ the rover's location at the one or more time moments *k* from the sets of residuals, the time offset between the clocks of the base stations, the sets of satellite-phase cycle ambiguities related to the baseline between the primary base station and the secondary base stations (optional), and an observation matrix. The estimation may be done by the previously-described methods. The means for performing this estimation step is provided by main processor 110 under the direction of an instruction set stored in memory 112, with the computed information being stored in data memory 114.

Please replace the paragraph at page 47, lines 16-20 with the following rewritten paragraph:

Keypad/display 115 may be used to receive an instruction from the human user to commence an estimation of the position of the Rover, and to provide an indication of the estimated position of the Rover to the user. For some applications, it may be appreciated that human **[[and]]** interaction is not required and that the keyboard/display would be replaced by another interface component, as needed by the application.

Please replace the paragraph at page 47, lines 23-27 with the following rewritten paragraph:

We demonstrate the preferred floating ambiguity resolution process using forms [12] - [17] above. It may be appreciated that the other previously-described embodiments of the present invention may **[[use]]** also **use** this floating ambiguity resolution process by simply

omitting forms and/or terms of forms from the process. The general view of the preferred ambiguity resolution process is to reduce the value of the following form during a series of epochs:

Please replace the paragraph at page 48, lines 6-10 with the following rewritten paragraph:

In form F_Σ, $\mathbf{\Delta_{1,0}\overline{N}}_k$ ~~represent~~ **represents** the combined vector of current estimates of floating ambiguities: $\mathbf{\Delta_{1,0}\overline{N}}_k = [\mathbf{\Delta_{1,0}\overline{N}^{L1}}, \mathbf{\Delta_{1,0}\overline{N}^{L2}}]$, and the following are used for the cases of q=1: $\mathbf{\Delta_{q,0}b}_k^{*\mathbf{L1}} = \mathbf{\Delta_{q,0}b}_k^{\mathbf{L1}}$, $\mathbf{\Delta_{q,0}b}_k^{*\mathbf{L2}} = \mathbf{\Delta_{q,0}b}_k^{\mathbf{L2}}$, $\mathbf{\Delta_{q,0}p}_k^{*\mathbf{L1}} = \mathbf{\Delta_{q,0}p}_k^{\mathbf{L1}}$, and $\mathbf{\Delta_{q,0}p}_k^{*\mathbf{L2}} = \mathbf{\Delta_{q,0}p}_k^{\mathbf{L2}}$. We have also broken down the weighting matrices $\left[\mathbf{C_n^{L1}}\right]^{-1}, \left[\mathbf{C_v^{L1}}\right]^{-1}$, *etc.,* as follows:

Please replace the paragraph starting at page 49, line 26 and ending at page 50, line 10 with the following rewritten paragraph:

An exemplary estimation process for the floating ambiguities according to the present invention employs form [31] in an iterative manner. We start at the initial epoch k=0 with the weighting matrix $\mathbf{D}_0$ set to the zero matrix, and an initial guess of floating ambiguities $\mathbf{\Delta_{1,0}\overline{N}}_0$ equal to zero. The first term of form [31] evaluates to zero for this initial epoch. We then generate a set of values for $\boldsymbol{\delta}\mathbf{X}_k$, $\Delta_{1,0}\tau_k$, $\boldsymbol{\delta}_{\mathbf{1,0}}\mathbf{I}_k$, $\mathbf{\Delta_{1,0}\overline{N}}_k$ at a first epoch k=1 which moves the value of F_Σ towards zero. This generates an initial estimate $\mathbf{\Delta_{1,0}\overline{N}}_1$ for the floating ambiguities and the rover's position (by way of $\boldsymbol{\delta}\mathbf{X}_1$). A weighting matrix $\mathbf{D}_1$ for the ambiguities is then generated, and a new set of values is generated for $\boldsymbol{\delta}\mathbf{X}_k$, $\Delta_{1,0}\tau_k$, $\boldsymbol{\delta}_{\mathbf{1,0}}\mathbf{I}_k$, $\mathbf{\Delta_{1,0}\overline{N}}_k$ at the next epoch k=2 which moves **the** value of F_Σ (k=2) towards zero. As a result, subsequent estimates $\mathbf{\Delta_{1,0}\overline{N}}_2$ and $\boldsymbol{\delta}\mathbf{X}_2$ are generated. This iteration process continues, with $\mathbf{\Delta_{1,0}\overline{N}}_k$ and $\boldsymbol{\delta}\mathbf{X}_k$ generally improving in accuracy as the iterations progress.

Please replace the paragraph at page 55, lines 6-8 with the following rewritten paragraph:

The means for performing **[[then]]** **<u>the</u>** above steps in rover 100 are provided by main processor 110 under the direction of instruction sets stored in memory 112, with the various computed data being stored in data memory 114.

Please replace the paragraph starting at page 56, line 5 and ending at page 57, line 1 with the following rewritten paragraph:

The columns are modified by substituting a value of -1 for each column element that would normally be zero in the identity matrix. The positions of columns of matrix $\mathbf{\Sigma}$ which are associated with satellites $\hat{s}^1$ and $\hat{s}^2$ correspond to the row positions of these satellites in the vector $\mathbf{\Delta_{1,0}\overline{N}}_k$. When matrix $\mathbf{\Sigma}$ is multiplied onto vector $\mathbf{\Delta_{1,0}\overline{N}}_k$, the floating ambiguities corresponding to satellites $\hat{s}^{L1}$ and $\hat{s}^{L2}$ remain unchanged, but the floating ambiguity associated with $\hat{s}^{L1}$ is subtracted from the other floating ambiguities in the L1-band, and the floating ambiguity associated with $\hat{s}^{L2}$ is subtracted from the other floating ambiguities in the L2-band. Next, a permutation matrix $\mathbf{\Pi}$ is generated, and is applied to matrix $\mathbf{\Sigma}$ to **~~generated~~** **<u>generate</u>** a matrix product $\mathbf{\Pi}\cdot\mathbf{\Sigma}$. **~~Permutation~~** **<u>The permutation</u>** matrix is constructed to move the $\hat{s}^1$ and $\hat{s}^2$ columns of matrix $\mathbf{\Sigma}$ to the first and second column positions of the matrix product $\mathbf{\Pi}\cdot\mathbf{\Sigma}$. The construction of permutation matrices is well known to the field of mathematics. A permutation matrix satisfies the following relationships: $\mathbf{\Pi}^\mathbf{T}\cdot\mathbf{\Pi} = \mathbf{\Pi}\cdot\mathbf{\Pi}^\mathbf{T} = \mathbf{I}$. Next, a change of variables for the cost function F is undertaken as follows:

Please replace the paragraph at page 58, line 17-19 with the following rewritten paragraph:

Having resolved the fixed-integer ambiguities, we can **[[new]]** **<u>now</u>** generate a further refined estimate of the other solvable unknowns: $\mathbf{\delta X}_k$, $\Delta_{1,0}\tau_k$, $\mathbf{\delta_{1,0}I}_k$. A third cost function is formed as follows:

Please replace the paragraph at page 59, line 8-10 with the following rewritten paragraph:

The means for performing **[[then]]** **<u>the</u>** above steps in rover 110 are provided by main processor 110 under the direction of instruction sets stored in memory 112, with the various computed data being stored in data memory 114.

Please replace the paragraph at page 60, lines 7-13 with the following rewritten paragraph:

With this information, the residuals (difference quantities) $\Delta_{q,r}b_k^{L1,s}$, $\Delta_{q,r}b_k^{L2,s}$, $\Delta_{q,r}p_k^{L1,s}$, and $\Delta_{q,r}p_k^{L2,s}$ of forms [4A-4D] are generated for each baseline (q, r), where (q, r) has the following pairings (B2, B1), (B3, B1), and (B2, B3). For each baseline, the solvable unknowns in forms [5A-5D] are $\Delta_{q,r}\tau_k$, $\mathbf{\Delta_{q,r}I}_k$, and $\mathbf{\Delta_{q,r}\overline{N}}_k$. Values are estimated from the residuals in a manner similar to that described **[[about]]** **<u>above</u>** for the primary baseline between the Rover and first base station. As an example, a cost function F(*) may be formed as follows:

Please replace the paragraph at page 61, lines 3-14 with the following rewritten paragraph:

The floating ambiguities may be estimated in an iterative manner as described above. We start at the initial epoch k=0 with the weighting matrix $\mathbf{D}_0$ set to the zero matrix, and an initial guess of floating ambiguities $\mathbf{\Delta_{q,r}\overline{N}}_0$ equal to zero. The first term of form [31] evaluates to zero for this initial epoch. We then generate a set of values for $\Delta_{q,r}\tau_k$, $\mathbf{\Delta_{q,r}I}_k$, $\mathbf{\Delta_{q,r}\overline{N}}_k$ at a first epoch k=1 which moves the value of F towards zero. This generates an initial estimate $\mathbf{\Delta_{q,r}\overline{N}}_1$ for the floating ambiguities. A weighting matrix $\mathbf{D}_1$ for the ambiguities is then generated, and a new set of values is generated for $\Delta_{q,r}\tau_k$, $\mathbf{\Delta_{q,r}I}_k$, $\mathbf{\Delta_{q,r}\overline{N}}_k$ at the next epoch k=2 which moves **<u>the</u>** value of F (k=2) towards zero. As a result, **<u>a</u>** subsequent **~~estimates~~** **<u>estimate</u>** $\mathbf{\Delta_{q,r}\overline{N}}_2$ is generated. This iteration process continues, with $\mathbf{\Delta_{q,r}\overline{N}}_k$ generally improving in accuracy as the iterations progress. The corresponding $\mathbf{H}\cdot\mathbf{Y} = \mathbf{B}$ form for this process (similar to form [32]) is as follows:

Please replace the paragraph at page 64, lines 6-9 with the following rewritten paragraph:

The corresponding fixed-integer ambiguities $\mathbf{\Delta_{q,r}\hat{N}}_k$ may be generated from the floating ambiguities $\mathbf{\Delta_{q,r}\overline{N}}_k$ by the same process described above with reference to forms [37] – [43] that **[[is]]** **<u>was</u>** used to generate the fixed-integer ambiguities associated with the primary ~~**base line**~~ **<u>baseline</u>** between the rover (R) and first base station (B1).

Please replace the paragraph at page 64, lines 10-12 with the following rewritten paragraph:

Having resolved the fixed-integer ambiguities, we can **[[new]]** **<u>now</u>** generate a further refined estimate of the other solvable unknowns: $\Delta_{q,r}\tau_k$ and $\mathbf{\Delta_{q,r}I}_k$. A third cost function is formed as follows:

Please replace the paragraph starting at page 64, line 10 and ending at page 65, line 8 with the following rewritten paragraph:

where the five terms of the form are the same as the second through sixth terms of form [45], except that floating ambiguities have been replaced by the fixed-integer ambiguities. The same estimation procedures used on form [45] may be applied above to form [51], except that only one iteration is needed, and matrix **D** is not generated or used. As a result, estimates for $\Delta_{q,r}\tau_k$ and $\mathbf{\Delta_{q,r}I}_k$ are generated. However, we prefer to perform some consistency checks on these estimates before providing **<u>them</u>** to the process that operates on the primary baseline between the rover and the first base station. Thus, we will denote these estimates with hat symbols as follows: $\Delta_{q,r}\hat{\tau}_k$ and $\mathbf{\Delta_{q,r}\hat{I}}_k$. After the estimates associated with the three ~~**base line**~~ **<u>baselines</u>** (q,r) = (B2, B1), (B3, B1), (B3, B1) have been generated for the k-th epoch, we have the following data:

Please replace the paragraph at page 65, lines 17-23 with the following rewritten paragraph:

If the above relationships are not satisfied, the ambiguities have been resolved incorrectly for at least one **~~base line~~** **<u>baselines</u>**, and the estimations of fixed ambiguity should be neglected. To address an incorrect resolution, new data may be taken, **<u>or</u>** various subsets of data may be **~~processes~~** **<u>processed</u>** to generate sets of ambiguities which satisfy the above relationships. After all three **~~between base receivers ambiguity~~** **<u>between-base receivers' ambiguities</u>** have been resolved and the above relationships are satisfied, the ambiguity vectors $\Delta_{2,1}\hat{\mathbf{N}}_k$, $\Delta_{3,1}\hat{\mathbf{N}}_k$, and $\Delta_{3,2}\hat{\mathbf{N}}_k$ are considered to be correctly fixed.

Please replace the paragraph at page 66, lines 4-12 with the following rewritten paragraph:

Next, we perform a consistency check on the ionosphere delays. In the following discussion, **[[we]]** the subscripts on the ionosphere delay differentials have sometimes been exchanged, but this is of no substantive consequence since $\Delta_{1,2}\hat{\mathbf{I}}_k = -\Delta_{2,1}\hat{\mathbf{I}}_k$, $\Delta_{2,3}\hat{\mathbf{I}}_k = -\Delta_{3,2}\hat{\mathbf{I}}_k$, and $\Delta_{1,3}\hat{\mathbf{I}}_k = -\Delta_{3,1}\hat{\mathbf{I}}_k$. The **~~between base receivers~~** **<u>between-base receivers'</u>** ionosphere estimations should satisfy the relationship

$$\Delta_{1,2}\hat{\mathbf{I}}_k + \Delta_{2,3}\hat{\mathbf{I}}_k + \Delta_{3,1}\hat{\mathbf{I}}_k = 0\text{, to within a tolerance value of } \pm\epsilon_2. \quad [54]$$

However, **~~measurements~~** **<u>measurement</u>** noise typically prevents these relationships from being satisfied to an acceptable tolerance level $\pm\epsilon_2$. To better satisfy [54], the following quadratic function is minimized to obtain new estimations $\Delta_{1,2}\tilde{\mathbf{I}}_k, \Delta_{2,3}\tilde{\mathbf{I}}_k, \Delta_{3,1}\tilde{\mathbf{I}}_k$:

Please replace the paragraph starting at page 66, line 22 and ending at page 67, line 1 with the following rewritten paragraph:

Before applying form [57], the vectors $\Delta_{1,2}\hat{\mathbf{I}}_k, \Delta_{2,3}\hat{\mathbf{I}}_k, \Delta_{3,1}\hat{\mathbf{I}}_k$ are preferably smoothed using **<u>a</u>** Kalman filtering scheme with a dynamic model based **<u>on</u>** the **~~above described~~** **<u>above-described</u>** **[[the]]** Gauss-Markov time model (forms [GM1] and [GM2] above).

Please replace the paragraph at page 67, lines 2-8 with the following rewritten paragraph:

The results of these ~~process~~ processes may be provided to the process which generates the ionosphere delay differentials for the baselines associated with the rover stations, specifically the differentials generated according to forms [26], [29], and [30]. For form [26], which generates $\Delta_{1,0}\tilde{\mathbf{I}}_k$, the results are provided as follows: $\Delta_{1,2}\mathbf{I}_k = \Delta_{1,2}\tilde{\mathbf{I}}_k$ and $\Delta_{1,3}\hat{\mathbf{I}}_k = \Delta_{1,3}\tilde{\mathbf{I}}_k$. For generating the ionosphere delay differentials according to form ~~[29] we~~ [29], we set $\Delta_{2,1}\mathbf{I}_k = -\Delta_{1,2}\tilde{\mathbf{I}}_k$. For generating the ionosphere delay differentials according to form ~~[30] we~~ [30], we set $\Delta_{3,1}\mathbf{I}_k = \Delta_{3,1}\tilde{\mathbf{I}}_k$.

Please replace the paragraph starting at page 67, line 29 and ending at page 68, line 3 with the following rewritten paragraph:

While it is preferable to interpolate the ionosphere delays using two baselines between three base stations, it may be appreciated that some ~~application~~ applications may achieve acceptable accuracy by [[only]] interpolating the ionosphere delays using only one baseline between two base stations. Such an example may be a road project where the road is relatively straight, as shown in FIG. 4.

Please replace the paragraph at page 68, lines 4-9 with the following rewritten paragraph:

Each of the above methods of generating the base station data and estimating the coordinates of the rover is preferably implemented by a data processing system, such as a microcomputer, operating under the direction of a set of instructions stored in computer-readable medium, such as ROM, RAM, magnetic tape, magnetic disk, *etc.* All the methods may be ~~implements~~ implemented on one data processor, or they may be divided among two or more data processors.

Please replace the Abstract of the Disclosure at page 100, lines 5-16 with the following rewritten Abstract:

Disclosed are methods and apparatuses for determining the position of a roving receiver in a coordinate system using at least two base-station receivers, which are located at fixed and known positions within the coordinate system. The knowledge of the precise locations of the base-station receivers makes it possible to better account for one or all of carrier ambiguities, receiver time offsets, and atmospheric effects encountered by the rover receiver, and to thereby increase the accuracy of the estimated receiver position of the rover. ~~**Base lines**~~ **Baselines** are established between the rover and each base-station, and ~~**a base line is**~~ **baselines are** established between the base stations. Navigation equations, which have known quantities and unknown quantities, are established for each baseline. Unknowns for the baseline between base stations are estimated, and then used to correlate and reduce the number of unknowns associated with rover baselines, thereby improving accuracy of the rover's estimated position.